In The Claims

Please cancel Claims 1 through 18 without prejudice.

Please add Claims 19 through 80 as follows:

1-18. (Canceled)

19. (new) A method of optimizing signal traffic in a multi-layer waveband switching (WBS) optical network with a multi-granular optical cross-connect (MG-OXC), comprising:

for a node in said network, constraining a first lightpath to a single port, thereby reducing a number of active ports required in said MG-OXC to handle an amount of traffic as compared with a number of active ports required by a combination of ordinary cross-connects to handle said amount of traffic.

20. (new) The method of optimizing signal traffic as recited in Claim 19 wherein said node further comprises a wavelength cross-connect (WXC) port, a waveband cross-connect (BXC) port, and a fiber cross-connect (FXC) port and said first lightpath is a bypass lightpath; and,
said method further comprising:

switching said bypass lightpath using said single port selected from the group including said WXC port, said BXC port, and said FXC port.

21. (new) The method of optimizing signal traffic as recited in Claim 20 wherein said node further comprises a wavelength add port, a waveband add port, and a fiber add port and said first lightpath is an add lightpath; and,
said method further comprising:

adding said add lightpath using said single port selected from the group including said wavelength add port, said waveband add port, and said fiber add port.

22. (new) The method of optimizing signal traffic as recited in Claim 21 wherein said node further comprises a wavelength drop port, a waveband drop port, and a fiber drop port and said first lightpath is a drop lightpath; and,
said method further comprising:

dropping said drop lightpath using said single port selected from the group including said wavelength drop port, said waveband drop port, and said fiber drop port.

23. (new) The method of optimizing signal traffic as recited in Claim 22 wherein said optical network further comprises: first and second wavelengths and first and second wavebands; wherein said node further comprises a WXC layer, a BXC layer, a FXC layer, a wavelength to waveband (WTB) multiplexer, a waveband to fiber (BTF) multiplexer, a waveband to wavelength (BTW) demultiplexer, and a fiber to waveband (FTB) demultiplexer; and,
said method further comprising:

constraining said first wavelength to pass from said WXC layer through said first WTB multiplexer to said BXC layer;

constraining said first waveband to pass from said BXC layer through said first BTF multiplexer to said FXC layer

constraining said second wavelength to pass from said BXC layer through said first BTW demultiplexer to said WXC layer; and,

constraining said second waveband to pass from said FXC layer through said first FTB demultiplexer to said BXC layer.

24. (new) The method of optimizing signal traffic as recited in Claim 23 wherein said network further comprises:

a first number of input ports in said WXC layer, wherein each said first number of input ports receives a lightpath from an at least one second node; and,

a second number of input ports in said WXC layer, wherein each said second number of input ports locally adds at least one lightpath; and,

said method further comprising:

constraining a minimum number of required input ports in said WXC layer equal to a sum of said first and second numbers.

25. (new) The method of optimizing signal traffic as recited in Claim 24 further comprising:

operating upon a first number of wavebands in said BXC layer, wherein said operating is selected from the group including cross-connecting, adding, dropping, and bypassing;

wherein said network further comprises:

a second number of wavebands demultiplexed from said FXC layer to said BXC layer; and,

a third number of wavebands with wavelengths multiplexed from said WXC layer to said BXC layer; and,

said method further comprising:

constraining a minimum number of required input ports in said BXC layer equal to a sum of said first, second, and third numbers.

26. (new) The method of optimizing signal traffic as recited in Claim 25 further comprising:

operating upon a first number of fibers in said FXC layer, wherein said operating is selected from the group including cross-connecting, adding, dropping, and bypassing;

wherein said network further comprises:

a second number of fibers demultiplexed from said FXC layer to said BXC layer; and,

a third number of fibers with wavebands multiplexed from said BXC layer to said FXC layer; and,

said method further comprising:

constraining a minimum number of required input ports in said FXC layer equal to a sum of said first, second, and third numbers.

27. (new) The method of optimizing signal traffic as recited in Claim 26 wherein said node further comprises a number of available WTB multiplexers and a number of available BTW demulitiplexers; and,

said method further comprising:

activating a number of WTB multiplexers no greater than said number of available WTB multiplexers and activating a number of BTW demultiplexers no greater than said number of available BTW demultiplexers.

28. (new) The method of optimizing signal traffic as recited in Claim 19 wherein said network further comprises a third waveband and a fiber; and,

said method further comprising:

constraining said third waveband to said BXC port; and,

constraining said fiber to said FXC port.

29. (new) The method of optimizing signal traffic as recited in Claim 28 wherein said network further comprises at least one first node pair, respective traffic for each node pair in said at least one first node pair, at least one bypass lightpath, and at least one lightpath overlapping at least one other lightpath; and,

said method further comprising:

determining balanced path routing for said respective traffic; and,

assigning wavelengths for said respective traffic according to a sequence comprising said at least one bypass lightpath followed by said one lightpath overlapping at least one other lightpath.

30. (new) The method of optimizing signal traffic as recited in Claim 29 wherein said network further comprises at least one lightpath in said FXC layer, and at least one lightpath in said BXC layer; and,

said method further comprising:

switching in sequence, first said at least one lightpath in said FXC layer at said FXC layer and then said at least one lightpath in said BXC layer at said BXC layer.

31. (new) The method of optimizing signal traffic as recited in Claim 30 wherein said network further comprises a plurality of links and wherein determining balanced path routing further comprises:

finding K-shortest routes for each pair in said at least one first node pair and ordering said K-shortest routes from shortest to longest;

determining a maximum link load over all links in said plurality of links; and,

selecting a route for a pair in said at least one first node pair having a lowest maximum link load.

32. (new) The method of optimizing signal traffic as recited in Claim 31 wherein each node in said at least one first node pair further comprises at least one fiber with at least one band, and wherein assigning respective wavelengths further comprises:

determining at least one set of node pairs from said at least one first node pair;

calculating a weight for each said at least one set of node pairs;

selecting a set of node pairs from said at least one set of node pairs having a largest weight;

grouping wavelengths assigned to each said respective traffic in a respective fiber from said at least one fiber and in a respective band from said at least one band; and,

constraining consecutive node pairs in said at least one first node pair from sharing a band from said at least one band.

33. (new) The method of optimizing signal traffic as recited in Claim 19 wherein said network further comprises at least one second node pair and respective traffic for each node pair in said at least one second node pair; and,

said method further comprising:

determining routing for said respective traffic with respect to K-shortest paths for each node pair in said at least one second node pair; and,

assigning wavebands to said respective traffic according to band number restrictions, port number restrictions, and a respective weight for said each node pair.

34. (new) The method of optimizing signal traffic as recited in Claim 33 wherein said determining routing further comprises determining K-shortest paths for said each node pair in said at least one second node pair, determining a respective interference length for each said K-shortest paths, and selecting a path from said K-shortest paths having a largest interference length.

35. (new) The method of optimizing signal traffic as recited in Claim 34 wherein said respective weight further comprises a quantity selected from the group including: a respective hop number for said each node pair, an inverse of said respective interference length, and the product of said respective hop number and said inverse of said respective interference length.

36. (new) The method of optimizing signal traffic as recited in Claim 35 wherein assigning wavebands to said respective traffic according a respective weight for said each node pair further comprises selecting a minimum respective weight able to satisfy said respective traffic.

37. (new) A method for enhancing survivability in a waveband switching (WBS) optical network, comprising the steps of:

selecting at least one back-up band-segment, wherein said at least one back-up band-segment is connected to first and second nodes; and,

switching traffic on at least one band-segment to said back-up band-segment, wherein said at least one band-segment is connected to said first and second nodes and is link-disjoint with respect to said at least one back-up band-segment.

38. (new) The method recited in Claim 37 wherein said at least one band-segment further comprises a first number of wavebands and said at least one back-up band-segment further comprises a second number of back-up band-segments, wherein said second number is at least equal to said first number; and,
wherein said switching further comprises switching traffic on each said first number of wavebands to a respective back-up band-segment in said second number of back-up band-segments.

39. (new) The method recited in Claim 37 wherein said switching further comprises switching respective traffic on each said at least one band-segment to a single back-up band-segment from said at least one back-up band-segment at a respective time, wherein each said respective time is different than remaining said respective times.

40. (new) The method recited in Claim 37 wherein said at least one band-segment comprises a first number of link-joint band-segments and said at least one back-up band-segment further comprises a second number of link-joint back-up band-segments, wherein said second number is at least equal to said first number; and,
wherein said switching further comprises switching traffic on each said at least one band-segment to a respective said at least one back-up band-segment at a respective time, wherein each said respective time is different than remaining said respective times.

41. (new) A method for enhancing survivability in a waveband switching (WBS) optical network, the method comprising:

switching traffic between first and second wavebands in a fiber.

42. (new) The method recited in Claim 41 wherein said switching further comprises switching traffic on said first waveband to said second waveband.

43. (new) The method recited in Claim 41 wherein said switching further comprises switching traffic on said first waveband to said second waveband and switching traffic on said second waveband to said first waveband.

44. (new) The method recited in Claim 41 wherein said second waveband is free of traffic; and,

wherein said switching further comprises switching in response to a failure of said first waveband.

45. (new) A multi-granular optical cross-connect (MG-OXC) switch comprising:

a waveband conversion element;

a wavelength conversion element; and,

a sub-wavelength element operatively arranged to add and drop sub-wavelength traffic.

46. (new) The MG-OXC switch recited in Claim 45 further comprising:

a fiber cross-connect (FXC), a waveband cross-connect (BXC), and a wavelength cross-connect (WXC); and,

a fiber to waveband (FTB) demultiplexer, a waveband to wavelength (BTW) demultiplexer, a wavelength to waveband (WTB) multiplexer, and a waveband to fiber (BTF) multiplexer; and,

wherein said waveband conversion element further comprises a waveband conversion bank, said wavelength conversion element further comprises a wavelength conversion bank, and said sub-wavelength element further comprises a transmit/receive (TX/RX) block and a digital cross-connect (DXC) electronics element.

47. (new) The MG-OXC switch recited in Claim 46 wherein said MG-OXC switch is a multiple-layer MG-OXC switch.

48. (new) The MG-OXC switch recited in Claim 46 wherein said MG-OXC switch is a single layer MG-OXC switch.

49. (new) An apparatus for optimizing signal traffic in a multi-layer waveband switching (WBS) optical network with a multi-granular optical cross-connect (MG-OXC), comprising:

for a node in said network, means for constraining a first lightpath to a single port, thereby reducing a number of active ports required in said MG-OXC to handle an amount of traffic as compared with a number of active ports required by a combination of ordinary cross-connects to handle said amount of traffic.

50. (new) The apparatus of Claim 49 wherein said node further comprises a wavelength cross-connect (WXC) port, a waveband cross-connect (BXC) port, and a fiber cross-connect (FXC) port and said first lightpath is a bypass lightpath; and,

said apparatus further comprising:

means for switching said bypass lightpath using said single port selected from the group including said WXC port, said BXC port, and said FXC port.

51. (new) The apparatus of Claim 50 wherein said node further comprises a wavelength add port, a waveband add port, and a fiber add port and said first lightpath is an add lightpath; and,

said apparatus further comprising:

means for adding said add lightpath using said single port selected from the group including said wavelength add port, said waveband add port, and said fiber add port.

52. (new) The apparatus of Claim 51 wherein said node further comprises a wavelength drop port, a waveband drop port, and a fiber drop port and said first lightpath is a drop lightpath; and,

said apparatus further comprising:

means for dropping said drop lightpath using said single port selected from the group including said wavelength drop port, said waveband drop port, and said fiber drop port.

53. (new) The apparatus of Claim 52 wherein said optical network further comprises: first and second wavelengths and first and second wavebands;
wherein said node further comprises a WXC layer, a BXC layer, a FXC layer, a wavelength to waveband (WTB) multiplexer, a waveband to fiber (BTF) multiplexer, a waveband to wavelength (BTW) demultiplexer, and a fiber to waveband (FTB) demultiplexer; and,
said apparatus further comprising:

means for constraining said first wavelength to pass from said WXC layer through said first WTB multiplexer to said BXC layer;

means for constraining said first waveband to pass from said BXC layer through said first BTF multiplexer to said FXC layer

means for constraining said second wavelength to pass from said BXC layer through said first BTW demultiplexer to said WXC layer; and,

means for constraining said second waveband to pass from said FXC layer through said first FTB demultiplexer to said BXC layer.

54. (new) The apparatus of Claim 53 wherein said network further comprises:

at least one first input port in said WXC layer, wherein each input port in said at least one first input port receives at least one lightpath from at least one second node and said at least one first input port comprises a first number of input ports; and,

at least one second input port in said WXC layer, wherein each input port in said at least one second input port locally adds at least one lightpath and said at least one second input port comprises a second number of input ports; and,
said apparatus further comprising:

means for constraining a minimum number of required input ports in said WXC layer equal to a sum of said first and second numbers.

55. (new) The apparatus of Claim 54 further comprising:

means for operating upon a first number of wavebands in said BXC layer, wherein said operating is selected from the group including cross-connecting, adding, dropping, and bypassing;

wherein said network further comprises:

a second number of wavebands demultiplexed from said FXC layer to said BXC layer; and,

a third number of wavebands with wavelengths multiplexed from said WXC layer to said BXC layer; and,

said apparatus further comprising:

means for constraining a minimum number of required input ports in said BXC layer equal to a sum of said first, second, and third numbers.

56. (new) The apparatus of Claim 55 further comprising:

means for operating upon a first number of fibers in said FXC layer, wherein said operating is selected from the group including cross-connecting, adding, dropping, and bypassing;

wherein said network further comprises:

a second number of fibers demultiplexed from said FXC layer to said BXC layer; and,

a third number of fibers with wavebands multiplexed from said BXC layer to said FXC layer; and,

said apparatus further comprising:

means for constraining a minimum number of required input ports in said FXC layer equal to a sum of said first, second, and third numbers.

57. (new) The apparatus of Claim 56 wherein said node further comprises a number of available WTB multiplexers and a number of available BTW demulitiplexers; and,

said apparatus further comprising:

means for activating a number of WTB multiplexers no greater than said number of available WTB multiplexers and activating a number of BTW demultiplexers no greater than said number of available BTW demultiplexers.

58. (new) The apparatus of Claim 49 wherein said network further comprises a third waveband and a fiber; and,

said apparatus further comprising:

means for constraining said third waveband to said BXC port; and,

means for constraining said fiber to said FXC port.

59. (new) The apparatus of Claim 58 wherein said network further comprises at least one first node pair, respective traffic for each node pair in said at least one first node pair, at least one bypass lightpath, and at least one lightpath overlapping at least one other lightpath; and,

said apparatus further comprising:

means for determining balanced path routing for said respective traffic; and,

means for assigning wavelengths for said respective traffic according to a sequence comprising said at least one bypass lightpath followed by said one lightpath overlapping at least one other lightpath.

60. (new) The apparatus of Claim 59 wherein said network further comprises at least one lightpath in said FXC layer, and at least one lightpath in said BXC layer; and,

said apparatus further comprising:

means for switching in sequence, first said at least one lightpath in said FXC layer at said FXC layer and then said at least one lightpath in said BXC layer at said BXC layer.

61. (new) The apparatus of Claim 60 wherein said network further comprises a plurality of links and wherein said means foe determining balanced path routing further comprises:

means for finding K-shortest routes for each pair in said at least one first node pair and ordering said K-shortest routes from shortest to longest;

means for determining a maximum link load over all links in said plurality of links; and,

means for selecting a route for a pair in said at least one first node pair having a lowest maximum link load.

62. (new) The apparatus of Claim 61 wherein each node in said at least one first node pair further comprises at least one fiber with at least one band, and wherein said means for assigning respective wavelengths further comprises:

means for determining at least one set of node pairs from said at least one first node pair;

means for calculating a weight for each said at least one set of node pairs;

means for selecting a set of node pairs from said at least one set of node pairs having a largest weight;

means for grouping wavelengths assigned to each said respective traffic in a respective fiber from said at least one fiber and in a respective band from said at least one band; and,

means for constraining consecutive node pairs in said at least one first node pair from sharing a band from said at least one band.

63. (new) The apparatus of Claim 49 wherein said network further comprises at least one second node pair and respective traffic for each node pair in said at least one second node pair; and,

said apparatus further comprising:

means for determining routing for said respective traffic with respect to K-shortest paths for each node pair in said at least one second node pair; and,

means for assigning wavebands to said respective traffic according to band number restrictions, port number restrictions, and a respective weight for said each node pair.

64. (new) The apparatus of Claim 63 wherein said means for determining routing further comprises means for determining K-shortest paths for said each node pair in said at least one second node pair, means for determining a respective interference length for each said K-shortest paths, and means for selecting a path from said K-shortest paths having a largest interference length.

65. (new) The apparatus of Claim 64 wherein said respective weight further comprises a quantity selected from the group including: a respective hop number for said each node pair, an inverse of said respective interference length, and the product of said respective hop number and said inverse of said respective interference length.

66. (new) The apparatus of Claim 65 wherein said means for assigning wavebands to said respective traffic according a respective weight for said each node pair further comprises means for selecting a minimum respective weight able to satisfy said respective traffic.

67. (new) An apparatus for enhancing survivability in a waveband switching (WBS) optical network, comprising:

means for selecting at least one back-up band-segment, wherein said at least one back-up band-segment is connected to first and second nodes; and,

means for switching traffic on at least one band-segment to said back-up band-segment, wherein said at least one band-segment is connected to said first and second nodes and is link-disjoint with respect to said at least one back-up band-segment.

68. (new) The apparatus of Claim 67 wherein said at least one band-segment further comprises a first number of wavebands and said at least one back-up band-segment further comprises a second number of back-up band-segments, wherein said second number is at least equal to said first number; and,

wherein said means for switching further comprises means for witching traffic on each said first number of wavebands to a respective back-up band-segment in said second number of back-up band-segments.

69. (new) The apparatus of Claim 67 wherein said means for switching further comprises means for switching respective traffic on each said at least one band-segment to a single back-up band-segment from said at least one back-up band-segment at a respective time, wherein each said respective time is different than remaining said respective times.

70. (new) The apparatus of Claim 67 wherein said at least one band-segment comprises a first number of link-joint band-segments and said at least one back-up band-segment further comprises a second number of link-joint back-up band-segments, wherein said second number is at least equal to said first number; and,
wherein said means for switching further comprises means for switching traffic on each said at least one band-segment to a respective said at least one back-up band-segment at a respective time, wherein each said respective time is different than remaining said respective times.

71. (new) An apparatus for enhancing survivability in a waveband switching (WBS) optical network, comprising:

means for switching traffic between first and second wavebands in a fiber.

72. (new) The apparatus of Claim 71 wherein said means for switching further comprises means for switching traffic on said first waveband to said second waveband.

73. (new) The apparatus of Claim 71 wherein said means for switching further comprises means for switching traffic on said first waveband to said second waveband and switching traffic on said second waveband to said first waveband.

74. (new) The apparatus of Claim 71 wherein said second waveband is free of traffic; and, wherein said means for switching further comprises means for switching in response to a failure of said first waveband.